Selecting The Right Transmission Line

A bargain transmission line ultimately may prove to be very expensive. WB2WIK tells you which feedlines to use and which to avoid.

BY STEVE KATZ, WB2WIK

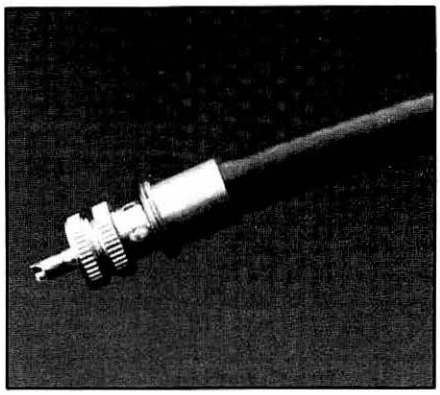
Coaxial cable has nearly universal acceptance for amateurs. Good coax contains the RF fields entirely within the outer conductor and, therefore, exhibits no radiation losses. Coaxial cables can be installed in close proximity to metal objects and other cables without noticeable interaction. It may be bound directly to metal antenna booms, masts and towers; many types can be buried underground for long periods without deleterious effect. Coax offers flexibility, both in application and installation, and is widely used throughout the telecommunications industry up to about 3 GHz. Put simply, coax is just plain easy to use!

The most important factors to amateurs facing the decision of which type of coaxial cable to buy will certainly include:

- Transmission loss
- Power-handling capability
- Service life
- Shielding effectiveness
- Flexibility
- Availability of compatible connectors
- Cost

Although I listed cost as the last consideration, thereby implying it is least important, I know from experience in speaking with thousands of amateurs that many consider a product's low price to be its finest attribute. While I'd surely condone shopping around for available bargains, I'd be remiss if I didn't point out that your transmission line can be the most important part of your station. After all, transmission line is as much a part of your antenna system as the antenna itself, and it plays an equally important role in your overall station gain equation.

Remember that a signal lost in your feedline is lost forever and cannot be brought back with a preamp on your receiver! VHF/UHF operators have entirely different problems in selecting a suitable coaxial cable than do HF operators. *Everything* is lossy at VHF and becomes lossier as the operation (radio) frequency is increased. Loss in coaxial cable can be estimated—if the electrical properties of the cable's components are known—as follows:



The "UHF" male connector, minus outer threaded sleeve, simply "screws" onto its mating cable when properly installed; the four connector-body solder holes should be completely filled with solder in an installation where proper heating (very rapid temperature rise, from a large *iron) was applied. A properly installed "UHF" connector* cannot *be pulled off its cable!*

$$A = 4.34\, R_t/Z_o + 2.78\sqrt{E \times pF}$$

where A is attenuation in dB/100′; R_t is the total line resistance in ohms/1000 ft.; Z_o is the characteristic impedance of the cable; E is the dielectric constant; p is the power factor of the dielectric medium at F; and F is the operating frequency in MHz.

The most common coaxial cable dielectrics are solid polyethylene and cellular polyethylene (often called "foam"), which have dielectric constants (E) of about 2.30 and 1.55, respectively. Power factor, p, is estimated to be .0002 for solid, and .00015 for cellular polyethylene. R_t can be measured or simply looked up in manufacturers' catalogs (e.g., R_t is about 3 ohms/1000 ft. for most RG8/U types), but this is DC resistance and does not include correction for "skin effects" at high radio frequencies. With so many uncertainties, the attenuation formula can derive only an estimate at best. I'd recommend contacting the cable manufacturers for more data.

Table I lists 12 popular coaxial cable types, many of which are "MIL standard" numbers available from several qualified suppliers, along with some of their key constructional and electrical parameters. The attenuation chart begins with an operating frequency of 50 MHz because it is at the higher frequencies that this becomes a vital statistic; at frequencies below 30 MHz even the smaller-gauge cables show almost inconsequential losses for reasonable line lengths, and such factors as power handling, flexibility and shielding effectiveness better qualify fitness for use.

For those whose situations dictate very long transmission lines, I recommend consulting manufacturers' published data for loss figures. Bear in mind that losses are a function of line-to-load matching. The best results will be

achieved when the load perfectly terminates the line (VSWR = 1.0:1).

The attenuation figures shown in Table I were derived via actual measurement by the author of 1000-ft. lengths of the cable types shown, then dividing measured losses by ten to establish the loss per hundred feet. This technique achieves more accurate results than would measuring the loss in 100-ft. lengths. Scanning the loss data, it is evident that a $\times 3$ increase of f_0 (operating frequency) yields about double the transmission loss for a given cable type. This relationship holds throughout the usable operating spectrum for coaxial cables; thus, the loss shown at 50 MHz for a given cable will be about half when used at 14 or 21 MHz, or about one-fourth when used at 3.5 or 7 MHz.

The results of my measurements did not always agree with manufacturers' published data. In some cases, my tests indicated cables to have *lower* losses than claimed by their suppliers! This may be explained by a number of theories.

I contacted a few of the major cable manufacturers who maintain military qualified production lines and facilities, and the consensus was that they guarantee worst-case losses and confirm their products to be within the ratings based on a mil-standard sampling plan; typically, losses will be somewhat lower than the guaranteed maxima to allow for random variations.

They also commended me for performing the tests described and for contacting them for further technical data correlation. One manufacturer's applications engineering manager commented that mine was the first technical inquiry his company had received from an amateur in nearly 20 years!

On the other hand, some of the non-mil "amateur" or "CB" grade cables do not appear to meet their rather optimistic transmission loss claims. One example is the "RG8/X" type cable, sometimes called "Mini-8" or "RG8/M." These are cellular (foam) dielectric types with stranded center conductors that are very easy to use and install due to their excellent mechanical flexibility. Unfortunately, they are *not* as low-loss as their true mil-grade (although larger diameter) counterparts, and most are severely contaminated after limited UV (ultraviolet) exposure, simulating one year's operation in equatorial daylight. This contamination is caused by reflow of plasticizers used in making jacket materials. It eventually breeches the outer conductor and changes composition of the dielectric material in a destructive manner, causing increased signal losses after typical weathering.

Possibly the newer "Mini-8" types are better than the ones I tested back in 1984, but after using perhaps 1000 feet total from a few different vendors, I wasn't impressed. I'll touch a bit more on this subject later.

Ironically, the "amateur grade" RG8/X cables cost nearly as much as mil-grade RG8A/U at the time, making the larger, more rugged cable a far better value. Of the types listed in Table I, I'd recommend only .405" and *larger* cables be used for antenna feedlines.

Good "deals" can be found on 7/8" and larger diameter flexible and "hardline" cables at amateur flea markets, or occasionally via equipment dealers. I personally purchased a few hundred feet of high-quality 0.875" diameter aluminum corrugated 50-ohm line (similar to RG332/U) from Prodelin, just before they relocated from New Jersey to North Carolina, for what I considered to be a "steal." The cable, which normally sells for more that $2 per foot, was available to local amateurs for just 45 cents per foot in nearly unlimited quantities back in 1982. Prodelin has since become a M/A Com division and moved its operations (and long since withdrawn this offer!), but similar deals can be found from time to time. (Incidentally, the mating connectors for this "bargain" cable sold for $48 each—I bought four of them, anyway. What good is the cable without the connectors?)

Some of the important characteristics of coaxial cable transmission lines, such as power handling, flexibility and service life, are ones which cable manufacturers do not often address in their published data. Thus, they must be determined experimentally or by years of experience. Sometimes even experience will not help, as in the case of new products. (See sidebar titled "The 9913 Story.")

In general, a cable's power-handling capability is related to its dielectric withstanding voltage rating, its ohmic resistance (which, in turn, is based on total conductor area), the thermal rise permissible (a function of insulation type), ambient temperature and barometric pressure, radio frequency of operation, transmitting duty cycle, and VSWR. Whew! Without writing a thesis on cable power ratings, I'll attempt to discuss trends and generalities, and recommend that you contact the cable manufacturer(s) for additional details when the need arises.

Table I
Coaxial Cable Specifications

Cable Type	Z_0 (ohms	O.D. (in.)	V.F.	Approx. Attenuation dB/100' by F_0*(MHz) 50	144	220	432	1296	Dielectric Type	Pwr. (W)	Notes
RG58/U	53.3	.195	66%	3.1	5.7	7.5	11	19	PE	100	1,2,3
RG141A/U	50	.190	69.5%	2.1	4.0	5.2	7.6	16	TFE	1500	1,4,5
RG59/U	73	.242	66%	2.4	4.2	5.4	7.8	14	PE	100	1,2,3,6
RG8/X Type	50	.242	78%	2.5	4.6	6.0	8.8	16	FPE	200	2,7,8
RG8/U, 213/U	52	.405	66%	1.6	2.7	3.5	5.2	10.7	PE	750	9
RG11/U	75	.405	66%	1.3	2.5	3.2	5.0	9.5	PE	750	9
8214 Belden	50	.405	78%	1.2	2.3	3.0	5.0	9.5	FPE	750	9,10,11
FM8 Times	50	.405	80%	1.2	2.1	2.5	3.5	6.5	FPE	1000	10,11
9913 Belden	50	.405	84%	.64	1.3	1.8	2.8	5.4	Air/PE	1500	9,11,12
RG331/U	50	.500	78%	.60	1.1	1.5	2.4	4.0	FPE	1500	9,13,14
RG17/U, 218/U	52	.870	66%	.50	1.0	1.3	2.3	4.4	PE	1500	14
RG332/U	50	.875	78%	.35	.65	.80	1.3	2.5	FPE	1500	13,14

Key to dielectric types: PE = solid polyethylene; FPE = cellular (foam) polyethylene; TFE = Teflon.
*Attenuation figures are based on actual measurement by author and may not agree with manufacturers' published data; consider these typical, not guaranteed. "Pwr" is recommended maximum power @ 144 MHz assuming T_a = 25°C and VSWR = 1.5:1; derate at higher frequencies, temperatures or VSWR.

Notes:
1. Not recommended for transmission line use above 50 MHz.
2. Recommended for low power mobile/portable installations where overall length does not exceed 50 feet.
3. Recommended for low power (and receiving) jumper cables and interconnects.
4. Recommended for baluns.
5. Withstands very high power and ambient temperature (200°C).
6. Recommended for low power matching sections, "Q" sections, etc.
7. Recommended for medium power mobile/portable installations; very flexible.
8. Handles 750 W @ 50 MHz, 300 W @ 144 MHz under ideal conditions.
9. Good general-purpose transmission line for use through 220 MHz, or 432 MHz when used in short lengths.
10. Cellular polyethylene dielectric cable with larger than normal center conductor diameter allows lower transmission losses than are possible with conventional RG8/U.
11. 2.74-mm diameter center conductor will not fit standard constant-impedance connectors (type N) without modification of cable or connector. Will fit "UHF" series connectors (PL-259) without modification.
12. Primarily air dielectric (spiral of solid polyethylene to hold center conductor in place) allows use of very large conductor diameter, resulting in much lower loss than RG8/U types. Recommended for transmission line use through 1296 MHz.
13. Solid aluminum outer conductor; cable cannot be flexed repeatedly and is not suitable for routing around rotator.
14. Requires special, dedicated connectors; standard RG8/U series connectors are not suitable (UG21/U type).

Transmission Lines: A Brief History

Transmission lines serve to conduct RF energy from one point to another, principally from transmitters to antennas or from antennas to receivers. In most amateur stations, a common line serves the dual role of conducting energy for both transmission and reception to and from a common antenna. This means the transmission line is very much a part of the station, either an extension of the transmitter/receiver or the antenna, depending upon the direction from which it is viewed.

In the early days of wireless communication, the wavelengths used were very long (thousands of meters). Signals generated were not confined to single frequencies (that came later, with the popularization of piezoelectric crystals or sharply tuned resonant circuits for frequency control). This created the need for very long wire antennas that were often connected directly to transmitters without impedance transformation, shielding and such matters. The single unshielded wire connecting the transmitter to antenna was thus part of the radiation system.

Later, when symmetrical, resonant antennas such as dipoles became popular, feedlines were often more suited to the high-impedance vacuum-tube transmitters employed, with little regard for achieving a match between the line and its terminating antenna. With operating frequencies still low and feedline losses small enough to be unimportant, large mismatches between line and load were of little consequence. However, operators were aware that their high impedance transmission lines, often "balanced" lines using closely spaced parallel conductors, radiated along with their antennas. They began using this questionable feature to their advantage. They tuned the lines with adjustable matching networks placed close to the transmitters at the feedline connection point, or they oriented the lines to complement or selectively cancel antenna radiation.

Even a perfectly matched (line:load impedance ratio of nearly 1:1) balanced line with minimal radiation will only operate properly in a very narrow frequency bandwidth. It will tend to radiate substantial energy as the operating frequency deviates from the critical match point. This is easily observed using RF field strength meters, or the way our forefathers did, using electric light bulbs connected in series with coupling loops.

Further, parallel wire transmission lines are adversely affected by ice, snow, rain and airborne contaminants, making them unsuitable in many environments. Laboratory tests have shown that at frequencies as low as 30 MHz, parallel line losses can multiply tenfold when the conductors are loaded with just one-tenth inch of radial ice coating, a not uncommon possibility in 70% of the populated places on our planet.

Enter coaxial cable! While newcomers to the hobby and the industry probably think coaxial cables have existed forever, old-timers will remember their actual introduction during World War II, when the American Phenolic Company (now Amphenol) developed the first concentric transmission lines by extruding polyethylene dielectric materials.

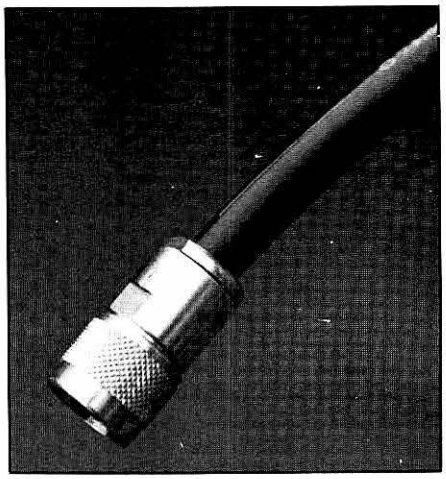
Based on considerable experimentation, it was determined that a characteristic impedance of about 30 ohms offers the best power-handling capability (a function of conductor size) while about 70 ohms offers the lowest transmission losses. Thus, 50 ohms characteristic impedance cable, the most popular choice for transmitting/receiving applications, is an excellent compromise for the best possible parameters of importance to amateurs.

Though there remain a few possible alternatives to coaxial cable, no other type transmission line offers so many advantages, so few disadvantages and such universal acceptance by the telecommunications industry. Much has been written about the low loss and high power-handling capability of balanced feedlines (now generally referred to as "open wire," "ladder line," or "twin lead"), but it is important to note that their relatively low transmission losses are possible under only the most ideal conditions.

As an example, parallel wire lines exhibit radiation losses, poor RF field containment and electrical properties that are highly dependent on operating environment. They must be routed carefully to avoid proximity to other conductors (including masts and towers!) and run as vertically as possible to reduce buildup of foreign materials such as ice and snow. Also, measurement of transmitted power, an FCC requirement when operating near the legal limit, is problematical because little in the way of commercial, lab-quality measuring instrumentation is available for these types of lines.

To interface higher-impedance transmission lines with 50-ohm station equipment and/or antennas requires the use of impedance-transforming "baluns" (*bal*anced to *un*balanced transformers). This is usually a poor alternative to using coaxial cable because balun losses are often higher than even mismatched transmission lines would introduce. Moreover, while conductor currents will be lower (for a given transmitter power level) with high-Z balanced lines, dielectric stresses will be higher because voltage across the lines will be greater. This makes nearly any insulator a possible "flash point" for corona inception, especially at higher power levels.

If corona discharge occurs, either between the conductors of a balanced line or between one side of the line and a nearby conductor, this can cause ignition of nearby combustible material, which creates a fire hazard. Don't think this can't happen —I might be tempted to divulge details of an incident that actually occurred at my own station a few years back, when the side of my home literally caught fire because the high-voltage point (end) of my 75-meter antenna was just a bit too close to my garage siding!



Properly installed type-N male connector on RG213/U cable. The type N has a one- or two-piece rubber gasket that forms a weatherproof seal between the cable jacket and connector rear nut, which should be tightened securely to clamp the assembly together. With just a bit of practice, professional installation is a two-minute job.

The cables offering the lowest transmission losses typically have the highest power ratings (or capabilities). However, this is not always the case. For example, 0.190"-diameter RG141A/U exhibits rather high transmission loss due to its small conductor size. Yet it can carry the amateur legal-limit power (1.5 kW) because its Teflon dielectric and jacket insulation has a very high withstanding voltage rating and can operate satisfactorily to about +200° C. At this temperature, standard polyethylene materials melt.

In fact, conventional polyethylene-dielectric, vinyl-jacketed RG-type cables are only rated to +80° C operation and therefore cannot tolerate extreme conductor heating without deterioration or destruction. So, where does this bring us? Well, it can be said that for a given insulation type, the larger the diameter of the cable and the lower its ohmic resistance, the more power it can handle.

Cable manufacturers are reluctant to rate power handling for transmission lines because so many variables affect this parameter. Based on personal experience, I've given some recommended maximum power limits for the popular lines listed in Table I. Possibly these figures can be safely exceeded, but at the levels shown these cables become warm. I hate to think what happens when this heat adds to surface temperature of the cable used outdoors on a sunny summer's day. Coaxial cable must be derated when ambient temperature, altitude above sea level or VSWR is increased.

Regarding flexibility: As a general rule stranded conductors are more flexible than solid ones. It is wise to select coaxial cables having stranded center conductors for applications requiring frequent and repeated flexing. But the cables offering the best shielding (maximum RF field containment) are usually the least flexible because they have solid or nearly solid outer conductors. There must be some compromising in this area if both shielding effectiveness and physical flexibility are important to you. In selecting a cable for outdoor use, remember that the insulators become less flexible at lower temperatures, especially below 0° C (32° F), and can become the restrictive element in overall suppleness.

How important is shielding? This is a very subjective question and depends upon the application. The common MIL-C-17 cables (called "mil spec," such as RG213/U, RG218/U, etc.) offer an appropriate amount of shielding for nearly any amateur application except, perhaps, duplex repeater work. High-quality mil-spec types, and many non-mil types, which are more affordable, frequently have 95% or better braid (shield) coverage. Extra-shielded cables such as RG223/U (the dual-shielded version of RG58A/U) or RG214/U (the dual-shielded version or RG8A/U) usually have two silver-coated copper braid shields and offer nearly 100% shield coverage.

These double-shielded cables exhibit much better shielding than their single-shielded counterparts, but they do *not* offer lower transmission losses! Thus, there is usually not good reason to use dual-shielded cables in any but the most stringent applications, such as full-duplex (repeater) operation with a single antenna.

Service life is related not only to operation within the cable's rated electrical and mechanical limits, but also to the jacket material composition. While the mil-spec cables have *non-contaminating* PVC jackets, meaning their polyvinyl-chloride plasticizer will not migrate and contaminate the dielectric material, many commercial cables (including RG "types") use polyethylene or standard PVC jacket material that can—and will—lead to early deterioration and shortened service life. It is important to select cables that offer at least the service life you desire; in some cases, this may be many years.

When in doubt about the type jacket material a particular cable has, call the manufacturer for guidance. If the cable is labeled "MIL-C-17" or "MIL SPEC," it should have a non-contaminating jacket. In the case of semi-solid ("hardline") cables or those which have a 100% laminated solid shield (e.g., the "Duobond II" shield used on Belden 9913), migration of the jacket plasticizer is unimportant because the dielectric is protected by a solid metal covering.

How much deterioration does a coaxial cable suffer from the contaminating effects of vinyl plasticizer migration? Based on one article written by an expert in this field, RG8/U, which exhibits about 3-dB loss per 100 feet at 144 MHz when new, can deteriorate to double this loss (6 dB/100 ft.) after "extended service." This article did not clearly define "extended service," but implied that the period of time required for this kind of deterioration, especially at frequencies above 1 GHz, may be as short as one year! The essentially identical RG213/U features a non-contaminating vinyl jacket that greatly extends outdoor cable life.

Terrific "deals" can be found, as mentioned earlier, on high-quality surplus coaxial cable suitable for amateur use. Some of the popular low-loss surplus types include RG17/U, 1/2″, 3/4″ and 7/8″ "hardline" and Heliax, etc. If these cables were treated properly, they can offer very low loss even after years of storage. But the "deal" may not seem so attractive when it comes time to buy connectors. Unless surplus connectors are available from the same source as the cable, you may have to purchase new connectors for your "bargain" feedline at several times the cost of the cable itself.

I'd recommend looking into available connectors and sources before spending any hard-earned cash on transmission

The 9913 Story

When I published my first article on transmission lines for the April 1985 edition of *CQ* ("VHF/UHF"), from which a good deal of the material presented here is borrowed, I had been using Belden 9913 cables for about nine months. This was virtually the product's entire market life. Over the years, I've found the cable an excellent choice for use in the 1.8-to 1296-MHZ spectrum (that's 14 amateur bands!) *if* the cable is installed judiciously. Based on my experience, I have the following recommendations regarding the use of 9913-type cables:

• Do *not* splice it, even using proper connectors and fittings, in outdoor applications and permanent installations. I installed a few line splices in 9913, using weather-resistant mil-type N fittings and "barrels" (double female coaxial adapters). Each splice was protected by numerous overlapping layers of weatherproof vinyl type (Scotch brand 88 electrical tape) in turn overcoated by a silicone-based sealant spray. I found that the splices take in a minuscule amount of moisture, which would not have impacted the performance of other cable types, but severely degraded line performance (causing a substantial rise in VSWR) in the VHF spectrum.

This problem repeated itself in four different lines, all "properly" spliced, over a period of two or three years. In each case, replacing the 9913 with solid-dielectric cable (RG213/U) similarly spliced *or* removing the splices altogether and replacing the lines with uninterrupted runs of 9913, solved the problems permanently. Apparently, even one small droplet of water introduced anywhere along a 9913 feedline absolutely destroys its performance, especially at VHF/UHF.

In one case, the VSWR of a 144-MHz system climbed from nearly perfect (1.1:1) to very poor (3:1) over a period of a few months. Random replacement of various portions of the 150'-long transmission line revealed the problem to be in a small length (about 50') of 9913 I had spliced into the line when raising the effected antenna.

Submitting this line section (which was terminated in shiny, new type-N connectors on both ends) to laboratory analysis revealed the problem to be an impedance "bump" midway along the length of the cable, as indicated by TDR (Time Domain Reflectometry) testing. Or was it? Shifting the line around the lab "moved" the impedance "bump" from one place to another.

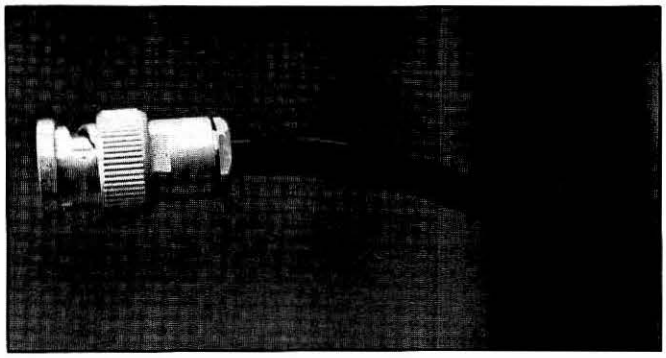
Drilling a small hole through the cable at the point of the apparent "bump" demonstrated the problem: A small amount of water was trapped in the cable, able to wind its way up and down the cable's length by following the spiral-shaped dielectric. As my friend Luther, WA2DTA (who performed the lab analysis at a Bell Communications Research laboratory) said, "The SWR ran out on the floor!" Ironically, this same cable, prior to drilling the vent hole, showed no real problems at frequencies below 144 MHz.

• Seal the exposed end very well. Based on a lot of experimentation, I found the cable performs best when only one outdoor termination is used (the connection to the antenna itself), and that connection point is very well weatherproofed with lots of "Coax Seal" or similar weather-proof dielectric putty.

• Route the cable around rotating joints (when used for rotary antenna systems) and around all required bends by making large-radius loops. A 24" radius, which is about 50 times the cable diameter, seems to work well and will withstand a lot of repeated flexing without degradation. Following the "large loop" rule, I have successfully used multiple runs of 9913 with "rotator loops" to feed antennas at frequencies as high as 1296 MHz (23 cm), through thousands of antenna rotations without deleterious effect on performance.

Table II
Coaxial Cable Manufacturers

Alpha Wire Corp., 711 Lidgerwood Ave., Elizabeth, NJ 07207
Amphenol Products, 2122 York Rd., Oak Brook, IL 60521
Andrew Corp., 10500 W. 153 St., Orland Park, IL 60462
Belden Electric Wire & Cable, POB 1980, Richmond, IN 47374
Cablewave Systems Inc., 60 Dodge Ave., N. Haven, CT 06473
Celwave, Rt. 79, Marlboro, NJ 07746
Chester Cable Corp., Oakland Ave., Chester, NY 10918
Decibel Products Inc., 3184 Quebec St., Dallas Tx 75247
ITT Suprenant Div., 172 Sterling St., Canton, MA 01510
JSC Wire & Cable, Burgess Pl., Wayne, NJ 07470
M/A Com, POB 1729, Hickory, NC 28603
Phalo Corp., 2 Friberg Pky., Westboro, MA 01581
Saxton Wire & Cable, 215 N. Rt. 303, Congers, NY 10920
Standard Wire & Cable, 2345 Alaska Ave., El Segundo, CA 90245
Times Fiber Communications Inc., POB 384, Wallingford, CT 06492
Uniform Tube, Microdelay Div., Collegeville, PA 19426



Here is a BNC male fitting on RG58A/U cable. This goes together much like a type N, but with smaller-scale components. Like the type N, the BNC contains a weatherproof gasket that fits between the cable jacket and rear nut to prevent moisture and contaminants from entering the connector.

lines which may be incompatible with any procurable fittings. Of course, some amateurs who have access to a well-equipped machine shop may choose to fabricate their own coaxial connectors. If proper care is exercised in their construction, home-brew fittings may work well enough, at least through 432 MHz.

Connector And Adapters

Although the popular "UHF" type PL-259 connectors fit the majority of equipment for the HF and VHF spectrum, their quality, and the quality of their installation, will play a key role in station performance. I recommend carefully avoiding the brightly-finished plated connectors (usually nickel, or nickel-chromium plated) often offered by distributors and at flea markets. Look instead for silver-plated, Teflon-dielectric "UHF" types, offered by reputable manufacturers such as Amphenol.

The silver-plated Teflon-dielectric connectors (83-1SP-1050) cost just a bit more money, but are far easier to install because solder flows so well, and at a lower temperature, to their silver-plated surfaces; further, they offer enhanced high-power performance because Teflon is a better dielectric material than the standard phenolic and rexolite types.

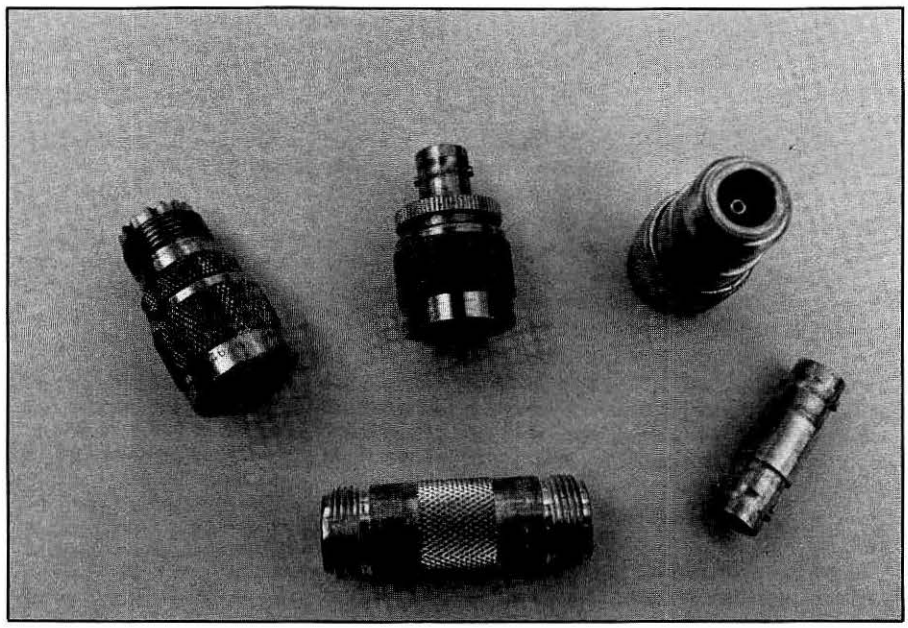
I've never found a "cheapie" connector worthy of purchase. In most cases, you want to install connectors just once and not have them be a source of problems. It's worth spending a few more dollars for high-quality fittings that will last the life of the cables and antennas you've installed.

When installing a "UHF"-type fitting, hold the connector rigidly to a ceramic soldering plate or other insulator (never clamp it in the metal jaws of a bench vise!) and apply sufficient heat from a powerful soldering iron or gun to allow rapid reflow of solder to the connector's surface, through the braid holes and into the coax braid. If this takes more than ten seconds, you're using an underpowered iron or doing something wrong.

Then allow the connector to cool back to room temperature without moving the cable or connector. This important step may take a few minutes, so be patient.

Next, solder the center conductor, allowing enough solder to flow so that the void in the connector center post is nearly filled. Let the center post cool to room temperature. Use a small burnishing tool (not a large file!) to remove any excess solder from the outer surface of the center post, and you're done.

Easier to install are type "N" fittings, which require no soldering, but rather clamping of the outer braid. Type "N" fittings, which are available for a wide variety of cable types, use a mechanical clamp to secure and bond to the coax braid; the center conductor of a type "N" usually requires soldering, but this is a simple matter. Because of the more precise geometry of the type "N" it is a "constant-impedance" connector, making it more suitable for VHF/UHF use. Type "N" connectors nearly always



A potpourri of coaxial adapters! Clockwise from the left: UHF female to type-N male; BNC female to type-N male; type-N female to UHF male (standing upright); BNC "barrel" (double female coaxial splice); and, at the bottom, a type-N barrel. While most adapters introduce some loss in the UHF region, the type-N in-series units, such as the type-N barrel shown here, introduce no measurable loss to at least 3 GHz.

have Teflon dielectrics. Since no soldering to the connector body is required, plating is less of an issue than with "UHF" types.

"BNC" fittings are another popular mil-standard series that require no braid soldering. Small in geometry, BNC's are most suited to smaller-diameter cables, such as RG58/U, and are very popular for use with interconnects or "jumpers." Most military equipment rated under 100 watts have these or their better-shielded brothers, type TNC, installed.

Type "C" series connectors are the larger versions of BNC, featuring the bayonet quick-disconnect benefits of the BNC in combination with the larger geometry of the type N. Not popular in amateur circles, these excellent fittings are often found terminating lengths of mil-surplus cable and are easily converted to more standard types via readily-available between-series adapters.

Speaking of adapters, as in all things, some are better than others. Steer clear of the cheapies, which often have clear or nearly clear dielectrics; also best avoided are the kinds with colored dielectrics (brown, blue, green). The best coaxial between-series adapters are silver plated with white Teflon dielectrics. The majority of good ones are American made, although some reasonably high-quality adapters, as well as connectors, are European.

I haven't seen any coaxial adapters or connectors from Japan or the other Asian countries worth buying. Possibly there are some, but they don't seem to make it to American markets. I try to buy only mil-grade connectors and adapters, readily identifiable by the military part numbers imprinted on them.

Securing Feedline To a Tower

How does one go about binding coaxial cable to antenna booms, masts, tower legs and like? The most likely answer is, "With lots of vinyl (electrical) tape," but there are surely other methods.

For example, if you've ever spent an afternoon, as I have, pulling 150′ of RG17/U up a tower (which usually involves ropes, pulleys, winches, "come-alongs," automobile bumpers and other accessories), you know full well that vinyl tape is not going to support the cable's weight against the tower leg unless some other means of presupport is assigned to the task. Some users are tempted to use stainless steel hose clamps for the job (well, they *are* strong!), but this is not advisable because the clamps have sharp edges that can damage the cable jacket or worse.

The proper attachment fixtures are available, however, usually from commercial tower manufacturers and installers. They're wire nets that enclose the cable for a length of a few inches and tie to the tower with hooks or clamps. Looking much like a "Chinese finger lock" game, these devices work beautifully and make the installation of large-gauge, heavy cables a simple exercise.

Now what about smaller RG8/U-size cables? Its simple installation tricks the user into a false sense of security. No special apparatus required here: Just some vinyl tape, lots of overlapping layers to make the binding tight and secure. Right? *Wrong!*

It is true that many overlapping layers of stretchable vinyl tape will dramatically increase pressure on the innermost (first) wrap, and that the proper way to use vinyl tape for wrapping is to pull it until it stretches a bit—perhaps 10% or more in length—as you wrap, leaving only the last wrap unstretched to avoid unwinding. This procedure is perfect for fixing a leaky pipe, but may be damaging to sensitive coaxial cables. Coaxial cables, especially the kind with cellular (foam) dielectrics, cannot withstand a great deal of mechanical stress. They are soft and flexible, making them a pleasure to work with—but the foam dielectric compresses easily, which can alter the impedance and withstanding voltage capability of the cable at any compression point.

I had a length of almost-new Belden 8214, a high-quality foam dielectric RG8/U type, short out entirely at a point where it was bound to a tower leg. It didn't short all at once, but slowly, over a period of weeks after installation. Probably exposure to hot summer sun, plus carrying legal-limit transmit power (in this case, at 50 MHz), helped the cable fail earlier than it would have. But when it did fail, it was exactly at a point where the cable was tightly bound to a tower leg (polyethylene is no match for steel) with several overlapping layers of vinyl tape. Upon removing the tape, I could see the cable literally collapsed, shorting the braid to center conductor and likely creating a spectacular flash upon occurance.

Not believing much in coaxial line splices, I replaced the entire length of cable, this time taping it a bit more gingerly to the tower leg (same vinyl tape, less gusto!) and never had another problem.

For those engineers among us who might think the feedline failure described was the result of a high-voltage node created by standing waves, I might point out that the feedline in question was terminated by a 50-ohm antenna system with measured VSWR of 1.12:1 at the antenna feedpoint of the frequency of operation (50.125 MHz), so this theory has little support.

Moral: Tape works fine, but use widely overlapping layers, spread over several inches of transmission line, rather than tightly binding the cable to a hard surface at just one point.

Summary

"Transmission lines. . .can't live with 'em, can't live without 'em." This line was intended to refer to women, I believe, but it seems appropriate.

Your transmission line, as an extension of your antenna system, is a very important element of your entire station. in some cases, especially at higher frequencies, the antenna feedline becomes as or more important than the antenna itself. After all, what good is a 20-dB gain antenna when it is all lost in the feedline to which it is connected?

At lower frequencies, where loss is not as much of an issue, RF containment (shielding) may be an important feature. if you've ever had TVI/RFI (television/radio interference) problems, especially with neighbors who were once friends, you'd probably welcome any means of reducing the trouble. A well-elevated antenna system, connected to a non-radiating transmission line, can often do the trick.

Repeater owners/operators will appreciate the enhanced performance available from just a minor improvement in transmission-line shielding. When you have a full-duplex station transmitting and receiving simultaneously with a single feedline and antenna, a very minor change in feedline or connector characteristics can have an enormous impact on station performance.

Lunar and meteor jockeys ("moon-bouncers" and stations which actively reflect signals off the ionized trails of random meteors) know how much a few tenths of a dB mean to station performance. Often working with signals that would be well below the noise level of most receivers, these folks well realize that a few dollars saved in transmission lines or connectors is no savings at all.

Yet, operators sometimes spend hundreds of dollars or more on their antennas and then skimp on the feedlines, trying to make do with a "bargain." A bit like buying a new Mercedes-Benz and then searching for a "deal" on motor oil.

Your transmission line is something that should last years, like your antenna, and is often not easily replaced. Consequently, it is wise to invest some time and money in the best feedline for the job, and then install it *properly*. Treat it with care and respect and it will work for you willingly, with neither salary nor benefits. The signal lost in your feedline cannot be recovered with the world's best preamp, so try not to lose it at all. Use the right line for the job, and the job will be more fun!